Determination of the ^{237}U(n,f)/^{235}U(n,f) cross sections using STARS+LIBERACE

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Reactions on unstable nuclei are at the core of nucleosynthesis in environments from stars to supernovae to the interior of nuclear weapons. However, the cross sections for many of these reactions are difficult to predict due to the influence of nuclear structure effects and unusual decay modes. These cross sections can be equally difficult to measure due to the short lifetimes and large backgrounds of the radioactive targets involved. The LLNL group is leading an effort to deduce neutron-induced reaction cross sections on unstable nuclei using a technique referred to as the surrogate reaction method. A surrogate reaction experiment involves measuring the decay probabilities of an intermediate nucleus populated using a light-ion induced reaction. The decay probability is determined through the coincident observation of the ejectile and a "tag" for a specific decay channel. The decay probability for channel x, P_x, would then be determined through the relation:

$$P_x(E_x) = \frac{N_x}{\varepsilon N_{ejectile}} \quad (1)$$

Where ε is the efficiency for detecting the residual nucleus tag, N_x is the number of residual nuclei tags observed for channel x and $N_{ejectile}$ are the number of coincident ejectiles observed The critical *ansatz* of the surrogate method is that the intermediate nucleus formed in both the light-ion induced and the neutron induced reactions is compound, i.e. its decay probabilities are independent of its formation. Recent work by Younes has shown [1] that for excitation energies 2.5 MeV or more in excess of the neutron separation energy the decay probabilities become independent of spin (the Weisskopf-Ewing limit). In the Weisskopf-Ewing limit the largest uncertainty in these measurements is the determination of $N_{ejectiles}$ due to contamination of the particle-singles spectrum from reactions on light contaminants in the target. A new approach was recently developed [2] where ratios of decay probabilities are used rather than the absolute decay probability itself. If the particle singles spectrum is similar for the two cases then the relative decay probability reduces to a ratio of "tagged" events:

$$\frac{P_x(E)}{P_y(E)} = \frac{N_x}{\varepsilon N_{ejectile}} \bigg/ \frac{N_y}{\varepsilon N_{ejectile}} = \frac{N_x}{N_y} \quad (2)$$

The first experiment to determine an unknown reaction cross section using this technique, ^{237}U(n,f), was performed in December 2004 using the STARS+LIBERACE spectrometer at the 88-Inch cyclotron at LBNL. A 55 MeV α-particle beam were used to excite ^{236}U and ^{238}U targets via inelastic scattering. Particle-fission coincidences were recorded and their ratios used to determine the relative cross section for neutron-induced fission of ^{237}U as compared to ^{235}U. This ratio was then multiplied the ^{235}U(n,f) cross section. The resulting cross section, together with two evaluations and a statistical model fission calculation from W. Younes [3] is shown in Figure 1. The calculation and the data are in excellent agreement with one another through second chance fission and differ significantly from the two evaluations.
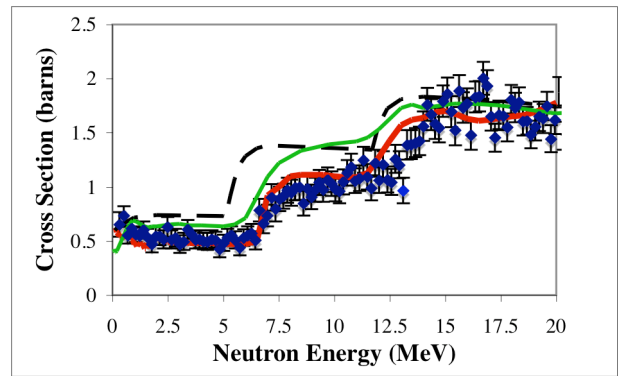
FIGURE 1: ^{237}U(n,f) cross section determined from the STARS+LIBERACE data (blue dots) compared to results calculations from W. Younes (red line), JENDL 3.3 (green line) and ENDF-B7 (dotted black line).

REFERENCES
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